Weatherwise

The Nature of Tornadoes

When Spring Arrives

An Airplane Flight Over a Tornado Path

The Tornado Cyclone

This Winter's Unusual Weather and Circulation

Vol. 2, No. 2, April, 1949

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE" — BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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LETTER TO THE EDITOR

Sir:

Most people have the idea that Arizona is all desert — dry and hot — partially because advertisers stress the sunshine angle. But one city in northern Arizona, hub city for travel to the Grand Canyon, Phoenix, or California, is decidedly not desert. Nestled in a huge forest of ponderosa pine (the largest standing yellow pine forest in the United States) at the base of the San Francisco Peaks, 12,611 feet high, is Flagstaff, itself at an elevation of 6,900 feet. The orographic and geographic features play a vital part in shaping our weather, summer and winter.

For 74 days, December 17, 1948, to February 28, 1949, Flagstaff was locked in the viselike grip of the most severe winter weather ever experienced by residents, young or old. Roads were clogged with snow, schools were closed for several days, automobiles that became stalled in driveways were soon completely covered. The sheriff's office organized snowshoe squads to aid isolated ranchers, and a ski-plane delivered groceries, landing on frozen lakes covered with snow.

Phenomenally, one could drive 30 miles east or 50 miles west and be out of the snow. If one could travel south 80 miles through the forest, snow was even deeper, and north to the Grand Canyon it was about the same as in the vicinity of Flagstaff.

Five days before Christmas, people began wondering if there would be a white Christmas. It began snowing on the 22nd and continued for the remainder of 1948. Ten days of storm in December produced 22.2 inches of snow that melted down to 3.38 inches of moisture; normal December precipitation is 1.98 inches. The month was relatively warm, mean temperature 30.7°.

After six more inches of snow on January 1st and 2nd, the sky began to clear and temperatures dropped to —20°. It was cold until the 9th, when the snow started again. It continued for 20 days and 20 nights to give us the heaviest snowfall ever recorded by official observers. In the first 16½ days of January, a total of 54.5 inches of snow fell in Flagstaff, and by the time it stopped snowing we had 104.8 inches in 31 days. January was the second coldest (mean 18.7°), second wettest, and the snowiest January in the 52 years that records have been kept. Total precipitation was 6.91 inches, total snowfall 104.8, normal precipitation 2.22 inches. On January 24th, 1.20 inches of precipitation fell as 19.9 inches of snow. At one time during the month there were 68 inches of snow on the level, with many drifts six to 15 feet deep.

Stockmen, worried about their cattle, called us to ask what February weather would be like. We went over the past records: more snow could certainly be expected in February, the 52-year average being 14.8 inches. Feed was flown by airplane and dropped near the cattle, then distributed by weasel tractors. The railroad plowed its lines clear, and fortunate cattlemen near the rail line shipped their cattle to lower valleys out of the snow and cold. Thirteen days in February it snowed, for another 26.9 inches and 1.64 inches of moisture. Conditions were

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Cover: An airplane view looking northeast at Warren, Arkansas, January 4, 1949, along the path of the tornado that struck northern Louisiana and southern Arkansas the previous day. Photo by McEachern. (See page 34.)

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The Nature of Tornadoes

S. D. FLORA, SENIOR METEOROLOGIST

UNITED STATES WEATHER BUREAU, TOPEKA, KANSAS

TORNADOES are the most violent and spectacular storms of the temperate zone. Often miscalled cyclones, they cause more havoc per unit area along sharply defined paths than any other natural phenomena. Despite much study of their nature, meteorologists have been unable to explain why on some occasions these storms occur whereas on others with the same set of known conditions tornadoes do not develop.

The distinguishing characteristic of a tornado is its writhing, funnel-shaped cloud whirling about a more-or-less vertical axis and moving across country at a normal rate of 30 to 40 miles per hour. The pendant cloud first develops aloft at the base of a cumulonimbus or mammatus cloud deck. So great is the turbulence in the cloud that laymen often describe the scene as that of "two clouds coming together." The funnel at the base of the cloud soon develops downward with a swaying motion, and if the apex touches the ground incredible destruction results to anything in its path. Dynamic cooling causes the condensation of water vapor, which makes the whirling air visible, often as a milky white cloud. As the water particles increase in size the cloud darkens, and when the vortex touches the ground dust and debris drawn into it make it almost black. Ordinarily, tornadoes are accompanied by great displays of lightning and heavy hail.

The basic cause of a tornado is the interaction of two contrasting air masses, one excessively warm and very moist, lying on the ground, the other much colder and relatively dry. The cold air overlies the warm air — a reversal of the usual stratification — and according to J. R. Lloyd, supervising forecaster of the Kansas City Weather Bureau, the warm layer is usually about 8,000 to 10,000 feet thick, moving from the south or southwest. The dry air, with a steep lapse rate, moves in from a westerly direction at an elevation of 5,000 to 6,000 feet. This shears off the top of the dome of warm,

This is very typical of many tornadoes in the prairie country of the West, with a long, slender vortex cloud. At the lower end dust can be seen as the cloud moves along the ground. A mass of whirling clouds is at the top. This photograph, from the author's collection, was taken near Burdett, Kansas, June 1, 1935. Like many other Kansas tornadoes, this one was outlined against a background of clear sky and traveled 12 miles without striking any buildings.

moist air, lifting it rapidly under the lid of dry air and causing extreme turbulence along the shear. Eddies form there that occasionally develop into a strong whirl, counterclockwise in the Northern Hemisphere, just as in the case of the ordinary much larger low-pressure cyclone disturbance. The speed of the whirl in a tornado is estimated at more than 300 miles per hour, two or three times that of a violent hurricane.

Pictures of tornado clouds show some of them as almost straight cylinders, while others are larger at the bottom than at the top and others are of hourglass shape. In rare instances, especially in its formative stage, the vortex exists as an immense whirling cylinder open at the bottom and high in the air. An opportunity to look directly into such a cloud was afforded Milton Tabor, present editor of the Topeka *Daily Capital*, who happened to be with a group of students just east of Lincoln, Nebraska, on the late afternoon of March 23, 1913, when the tornado that a few minutes later was to cause an appalling disaster at Omaha seems to have originated directly over their heads. He describes the sight as follows:

This is one of three tornadoes that formed near Ramona, Kansas, August 25, 1941, at about the same time and within a few miles of each other. Damage, all to rural property, totalled $70,000. Six persons were injured but none killed. Photo from the author's collection.

"The tornado cloud formed near where we were enjoying a picnic and whirled furiously high in the air straight over our heads. We looked up into what appeared to be an enormous hollow cylinder, bright inside with lightning flashes but black as blackest night all around. The noise was like 10 million bees, plus a roar that beggars description."

Tornadoes usually occur in the southwest or warm sector of a well-developed area of low pressure. Colder air lies a short distance to the northwest. Meteorologists can recognize these conditions and give a general forecast of the area where such storms may develop, but it is impossible to tell just when and where such a storm will form. Lloyd has shown that, in general, tornadoes travel across the country parallel to well-defined fronts on the weather map. This is usually from southwest to northeast, but with many minor exceptions. A tornado in Sedgwick County, Kansas, on June 20, 1942, formed two miles west of Mulvane, passed south of town, then turned and moved very slowly toward the northwest, ending about a mile north of the town. In the open country of the Middle West, warnings are often telephoned to communities in the indicated tornado path. In several places, the Weather Bureau has established a network of reporting stations to the south and west of cities so that immediate warnings can be broadcast by radio as a tornado approaches.

Paths of these storms vary greatly in width and length. From 15 to 100 yards is common for their width, but paths almost a mile wide have been reported. In Kansas, the average length is 10 miles, as computed from several hundred storms, but the average for the United States as a whole is at least 30 per cent greater. One of the longest paths on record in Kansas is that of a tornado that struck Hutchinson on May 8, 1927, and which traveled 102 miles. In eastern states, several storms have traveled 200 to 300 miles before dissipating.

There is a general belief that Kansas, often miscalled the "cyclone state," is the place of the most frequent occurrence of tornadoes. When relative areas are considered, records show that Iowa and Arkansas

lead in this respect, and several states and the District of Columbia have had nearly as many or more tornadoes per unit area. The following table is of the average occurrence of tornadoes over the 22-year period ending with 1937. The areas are in square miles; the average is of the number of storms per year; and the unit area number is the average annual number of storms for each 10,000 square miles.

State	*Area*	*Average*	*Per Unit Area*
Iowa	56,147	15.3	2.7
Arkansas	53,335	10.1	1.9
Kansas	82,158	14.6	1.8
Mississippi	46,865	6.0	1.3
Alabama	51,998	5.8	1.1
Missouri	69,420	6.7	1.0
District of Columbia	100	0.2	20.0

Damage from tornadoes has been greatest in states from Missouri east to Ohio and in a number of southern states; chief factors are the longer storm paths and the greater density of population and buildings. In 22 years ending with 1937, Missouri had nearly 33 million dollars property damage with loss of life totaling 355; Illinois lost 30 millions and 814 lives; Georgia lost 20½ millions, 433 lives; Texas 14 millions, 441 lives; Kansas over 12 millions, 102 lives; Alabama 11 millions, 611 lives.

A person who has seen a tornado or passed through one is never likely to forget the experience. The usual type of frame building is subject to total destruction by the full force of a tornado, although it may escape with the loss of only a wall or roof. Brick or stone buildings two or three stories high, so common in the business sections of cities, usually suffer collapse of the upper stories and have roofs blown off, but are seldom demolished to their foundations. There is some question whether or not a modern steel-reinforced concrete office structure or hotel, with the numerous partitions that exist in such buildings, can withstand a direct hit of a fully developed tornado without material damage. The Right Reverend Middleton B. Barnwell, bishop of the diocese of Georgia, in a letter dated May 27, 1947, refers to the tornado of February 10, 1940, which killed 17 persons and caused a loss of five million dollars.

"I cite to you the case of Albany, Georgia,

some years ago, when the Hotel Gordon was exactly in the center of a tornado's path. On both sides of the hotel buildings were lifted in the air. The A. & P. store was lifted bodily and deposited many blocks away. The hotel was of reinforced concrete construction, lost every window in it, was inspected after the storm for structural injury, and functions today as a very satisfactory place to stay. I have been there in recent storms and feel no fear whatever."

Freakish occurrences during tornadoes are almost beyond belief. Substantial buildings have been demolished while flimsy ones within a few feet remained undisturbed. Straws have been found blown into trees and fence posts so firmly they could not be pulled out without breaking. A rafter from an old barn near Topeka was driven through the siding and two-inch sill of a nearby house at a speed so terrific the pointed and partly weathered end of the rafter showed no battering effect whatever. Once a dresser was carried from a house that was demolished and set down against a fence at a considerable distance with the glass mirror not even cracked.

Pieces of straw driven into wood by the violent winds of a tornado. U. S. Department of Agriculture photograph.

Farm animals have been killed in great numbers by tornadoes. Several years ago in Norton County, Kansas, a tornado struck a herd of steers, drawing them up to a great height. Persons who saw them reported they looked like gigantic birds. Chickens are sometimes completely stripped of their feathers and killed, but occasionally an entirely naked chicken survives. One Louisiana rooster was conveyed several miles and set down in a flock of strange hens. Papers, including checks, have been carried 50 miles by these storms.

A person in an automobile can easily outrun or escape a tornado by driving at right angles to its path. A person on foot can usually get away by running at right angles, preferably toward the northwest, as winds seem to be less violent in that sector. One of the most common refuges is the southwest corner of the basement of a frame house, close to the wall. Since tornadoes usually approach from the southwest, debris is not likely to be blown into that corner, although the opposite side of the basement is often filled with missiles. The basement of a brick or stone house is exceedingly dangerous, as bricks or stones are likely to drop into it. Many farms in the Middle West have outdoor caves in which families have passed through tornadoes in complete safety in hundreds of reported instances.

Lying down in any depression when a tornado is about to strike is infinitely better than remaining upright since the air is likely to be filled with broken timbers as deadly as shrapnel. Many persons have saved themselves by crouching down against creek banks and crawling into culverts. In a down-

(Continued on page 39)

SOME DESTRUCTIVE TORNADOES IN THE UNITED STATES (1890 - 1949)

Place	*Date*	*Deaths*	*Loss In Dollars*
Louisville, Ky.	Mar. 27, 1890	106	3,500,000.
St. Louis, Mo.	May 27, 1896	306	12,904,000.
Omaha, Neb.	Mar. 23, 1913	94	3,500,000.
New Albany, Ind.	Mar. 23, 1917	45	2,000,000.
Fergus Falls, Minn.	June 22, 1919	59	3,500,000.
Chicago, Ill. & vicinity	Mar. 28, 1920	28	3,000,000.
Lorain-Sandusky, Ohio	June 28, 1924	85	12,000,000.
Missouri-Illinois-Indiana	Mar. 18, 1925	689	16,500,000.
St. Louis, Mo.	Sept. 29, 1927	72	22,000,000.
Tupelo, Miss.	Apr. 5, 1936	216	3,500,000.
Gainesville, Ga.	Apr. 6, 1936	203	13,000,000.
Albany, Ga.	Feb. 10, 1940	17	5,000,000.
Pryor, Okla.	Apr. 27, 1942	52	3,000,000.
Akron, Ohio	Apr. 27, 1943	2	3,000,000.
Ohio-West Va.-Pa.	June 23, 1944	153	5,000,000.
Louisiana-Arkansas	Jan. 3, 1949	50	———

WHEN SPRING ARRIVES

S. S. VISHER
PROFESSOR OF GEOGRAPHY
INDIANA UNIVERSITY

WHEN THE YEAR is divided into quarters equal in length, spring is, of course, the quarter between winter and summer. Where the calendar months are used to make the boundary, spring commences with March. Where the astronomical migration of the sun is used as the basis, spring starts with the vernal equinox, when the sun crosses the equator as it moves northward and day ceases to be shorter than night.

When average temperatures are used as the basis for the seasons, and only four seasons

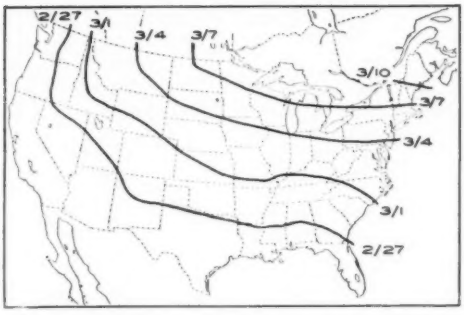


Fig. 1. Dates when the spring quarter commences, between the year's coldest and warmest quarters.

are recognized, spring is the quarter between the coldest and the warmest parts of the year. This varies in different parts of the country. Fig. 1 shows that on the basis of daily normal temperatures (the average of day and night together for many years) spring commences in late February in much of the South and far West. In a belt extending from North Carolina to Idaho it starts about March 1st, while in the Northeast it begins a week or so later.

As spring, according to the common conception, means temperatures normally above freezing, the date when the daily normals rise above 32° is also sometimes used as the date for the beginning of spring. On this basis, spring comes to the upper South generally about February 1st. Fig. 2 shows that the deep South continuously has daily normals

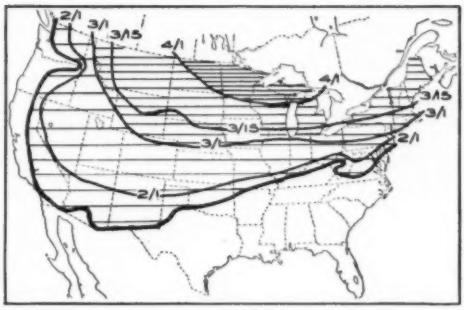


Fig. 2. Dates when spring starts if it is defined as the season when daily normal temperatures rise above 32° F.

above 32° and hence, on this basis, is classed as having a winter with springlike average temperatures. Spring generally starts about March 1st in a belt extending from Boston, New York, Pittsburgh, to Omaha and northwestward. This kind of spring comes about March 15th in central New York, and near Detroit, Milwaukee, and Sioux City.

Although daily normals of 32° may logically be considered as the beginning of spring, many people rightly feel that warmer temperatures are needed before spring actually arrives. If daily normals of 50° are used, the average dates of arrival of spring are those shown in Fig. 3. Such a temperature occurs about February 1st in the very deep South; it arrives about April 1st in a belt from Virginia to Kansas, but not till May 1st or somewhat later in much of the North.

These three maps (which are original, based on abundant official data) clearly show that the common statements that spring commences on March 1st or on March 21st are inadequate.

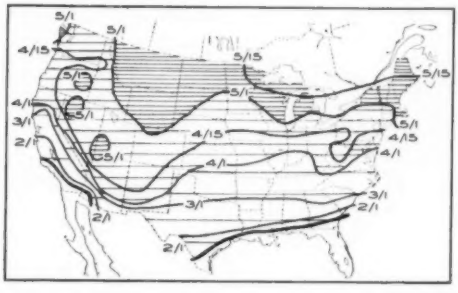
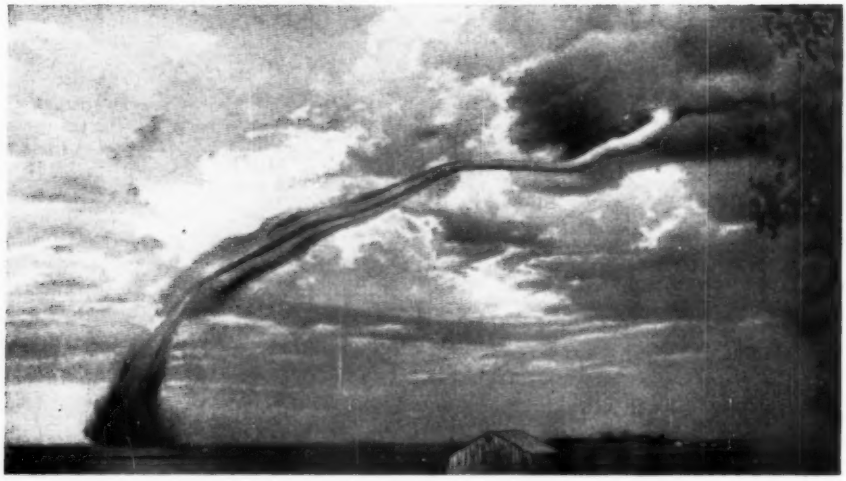


Fig. 3. Dates when spring certainly has arrived, when daily normal temperatures rise to 50° F.



The classical photograph of a tornado taken by Miss Lucille Handberg near Jasper, Minnesota. From *The Elements Rage*, by Frank W. Lane.

The Tornado Cyclone

EDWARD M. BROOKS, INSTITUTE OF TECHNOLOGY, ST. LOUIS UNIVERSITY

LAST YEAR in St. Louis, nature provided an unusual opportunity for the study of tornadoes. Within 30 miles of the city, tornadoes hit the earth's surface on four different days (Feb. 27, Mar. 19, Mar. 26, and May 1) and appeared aloft on three other days (Apr. 7, May 15, and Aug. 28). The tracking of known tornadoes forms the basis for the Weather Bureau's new tornado warning service in St. Louis, Kansas City, and Wichita, and the study of the phenomenon that shall be here called the *tornado cyclone* appears to be important in the tracking of tornadoes.

Although a tornado is very local, it is often attended by high winds and sudden reductions in pressure for distances as much as five miles away from it. The wind and pressure system over this area is the tornado cyclone, intermediate in size between the general parent low and the tornado funnel itself. During the last 50 years, there have been many cases of a tornado hitting a large city, where the Weather Bureau office experienced the winds and pressure changes of the tornado cyclone but not the tornado itself.

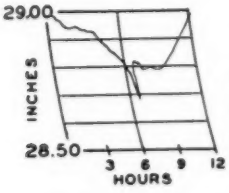
The tornado of March 19, 1948, seemed to be within a tornado cyclone while it was northwest of St. Louis. At the St. Louis Airport, 2½ miles southeast of the tornado path, the Friez microbarograph registered a sudden drop of three millibars followed by a sudden rise of five millibars, all within 15 minutes. By coincidence, the 6:30 a.m. (CST) observation was taken when the lowest pressure occurred and the synoptic map actually shows the presence of this tornado cyclone as a lower pressure at St. Louis than at surrounding stations. The wind did not suggest such a phenomenon, as it was only 17 miles per hour from the south-southeast. Consequently, the average map analyst would have ignored the pressure (as it appeared too low to be representative) and would have failed to identify the tornado cyclone. Thus, even at those rare intervals when a tornado cyclone may occur at a weather station at observation time, it may not be recognized on the weather chart for that time.

During the passage of the tornado cyclone, the highest average wind speed for one minute at the St. Louis Airport was only 22 miles per hour. Yet, at a point 4½ miles southeast of the tornado, the writer observed wind

speeds of force 8 from the south with tremendous gusts of well over 50 miles per hour. Similar strong winds from the west were occurring on the other side of the tornado path. These observations, taken simultaneously at 6:15 a.m., indicated an incomplete ring of strong tornado-cyclone winds that were entirely separate from the tornadic winds in the funnel. If the tornado cyclone had not contained the funnel, it would have had a wind distribution somewhat like that of a very small hurricane with an eye.

The 6:30 a.m. map showed an upper air cold front followed by a surface cold front. The tornado cyclone was located on the latter. This suggests that the tornado cyclone was originally a wave of very short wave length and small amplitude on the cold front. This wave probably occluded rapidly as a strong cyclonic circulation developed over a small area around it, and carried the two air masses around each other so many times that they formed a homogeneous mixture, as in a hurricane. The precipitation maximum on the left side of the tornado cyclone (looking downwind) was typical of a fast-moving hurricane or small wave on a cold front.

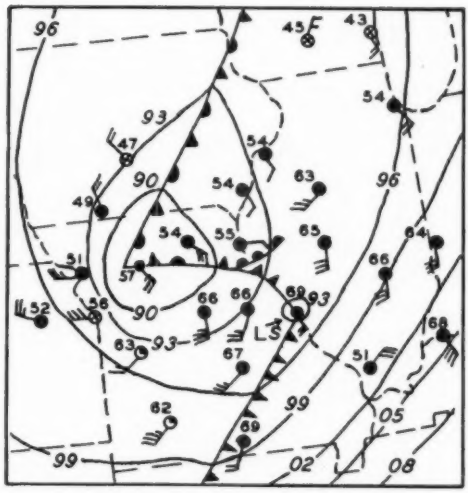
The tornado that wrecked Illinois towns on March 19th was not only larger, but also had more destructive winds than the other 1948 tornadoes, even though it resembled them while it was northwest of the St. Louis Airport. Although the expansion of this tornado as it traveled from Missouri to Illinois might be explained by involvement of the surrounding air by lateral friction, such a theory would call for a spreading out and consequent reduction of wind energy, contrary to fact. A much more reasonable explanation



Microbarograph trace showing the sudden dip at 6:30 a.m. on the morning of March 19, 1948.

would be that the tremendous energy was gained by a contraction rather than an expansion. Since the funnel itself did not contract, it must have been the tornado cyclone itself that did so.

By the principle of the conservation of angular momentum, a wind of 50 miles per



The synoptic situation on March 19, 1948, showing temperatures and wind barbs at the time the tornado cyclone was centered over the St. Louis station (LS).

hour at a distance of five miles would become a wind of 500 miles per hour at a distance of one half a mile from the center of rotation. Even if friction with the ground dissipated half of the kinetic energy, this would still leave a wind of about 350 miles per hour, which seems to be large enough for a severe tornado. Such a contraction would require a large upward motion and subsequent condensation within the tornado cyclone. This is verified by precipitation so heavy that no one could see the tornado funnel in Fosterburg or Bunker Hill, Illinois. The contraction of the tornado cyclone took place apparently aloft between the St. Louis Airport and the Mississippi River. By the time it descended in Alton the light wind area observed at the airport had been wiped out, the inner and outer winds violently merging. Although the tornado in Illinois was not called a new tornado, it probably represented the original Missouri tornado merged with its surrounding tornado cyclone. Its translation speed was over 50 miles per hour.

Tracking the tornado cyclone should be as important as tracking individual cyclones. Its size should make it more likely for a weather observer to detect the brief high winds and sudden pressure changes that characterize the tornado cyclone.

AN AIRPLANE FLIGHT OVER A TORNADO PATH

B. P. HUGHES, U. S. WEATHER BUREAU
SHREVEPORT, LOUISIANA

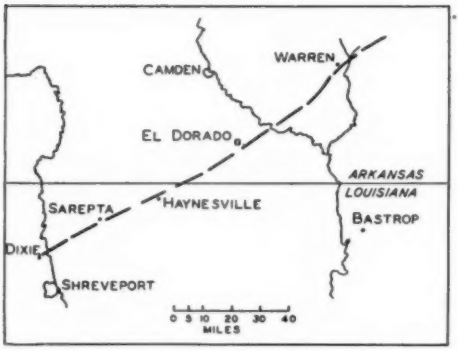
ON JANUARY 3, 1949, what appeared, from surface reports, to be a series of tornadoes developed over northern Louisiana and southern Arkansas. Reports of the sighting of a funnel cloud were received from Dixie, Louisiana, about 1:45 p.m. Later reports came in of damaging winds at several communities to the northeast of Shreveport, with property damage and loss of life at Haynesville, El Dorado, and Warren. At the last-named community, where damage and loss of life were heaviest, the tornado occurred about 5:45 p.m. In locating on a map the places of reported damaging winds, it was noted that they were nearly in a straight line and the times of occurrence were consecutive. This led to the belief that only one tornado was involved. A couple of days later, in discussing tornadoes with Colonel A. C. Strickland, commandant of Barksdale Field, Louisiana, the colonel offered to furnish a bomber and crew for a look at the tornado from the air. Needless to say, the offer was very happily accepted.

On the afternoon of January 6th, in the company of Major Carter, Barksdale Base weather officer, we took off and headed directly for Warren. After about 40 minutes in the air, the path of the tornado was picked up approximately 2½ miles to the west-southwest of that community. Wheeling into line above the path, the plane was headed along the track through Warren and out into the open country beyond. From where the path was first observed, it went in a northeasterly direction until it was lost approximately 10½ miles out from town. From the air, it was

The tornado that approached Lincolnville, Kansas, on August 25, 1941. The top picture was taken when the twister was about three miles away, and shows the dark menace as it first struck the ground. The middle picture was made when the funnel was about a mile away, the tornado at the height of its fury. In the last picture, from a distance of half a mile, the storm was swerving from its path as it began to disintegrate. Photographs by Mrs. Omar Shields, USWB.

easily apparent that the storm dissipated there. The path of complete destruction faded into only occasional fallen trees in the last two miles.

The plane then reversed its course to obtain a closer look at the destruction in Warren. Damage there was confined to the southern edge of that city of about 7,500 persons. For a width of about 100 yards in the center, destruction was complete (front cover). Not a thing appeared to be standing in the center, with gradually decreasing damage for about 200 or 300 yards on each side of the center. In the drying yard of a lumber mill, several acres in area, it was noted that piles of lumber had completely disappeared in the center of the path, while short distances to the side they appeared untouched. In the center of the path through Warren the ground had much the appearance of having been polished by a gigantic power buffer, reflecting light like a strip of polished floor.



Tornado destruction path, January 3, 1949.

A little weaving of the track was visible, but the deviation from a straight line was remarkably small. The location of the path through Warren was fortunate, for if it had been 200 or 300 yards to the left deaths might have been several times the 53 reported.

On the return trip, we decided to attempt to trace the path to its origin, if possible. Extremely heavy rains must have accompanied the storm, as much water still lay on the ground and several highways were still flooded for short distances as we passed over nearly three days after the storm's occurrence. Southwestward from Warren, along a line indicated by the direction of the path, another strip of damage was next noted near El Dorado, some 45 miles southwest of Warren. Here the visible track was short, about four miles, but with the axis in the same direction. On the same course, the path was picked up again about 30 miles farther to the southwest, where some homes were demolished and some lives lost near Haynesville, Louisiana. Approximately 15 miles farther, the path again appeared for about 2½ miles on the northern edge of Sarepta, with damage complete in the center. Fortunately only two homes were involved. The flight southwestward was continued another 25 miles to Dixie, where the funnel cloud had been first reported. One house was found unroofed, but there was little indication of a tornado path. No evidence of damage was discovered west of Dixie.

A checkup of the survey indicated that only one tornado was involved or, at least, that only the one cloud formation produced the tornadoes, if there were more than one. As stated, a funnel-type cloud was reliably reported at Dixie and the path of damage, although having breaks of up to about 45 miles, pursued a steady course of near 50° until it dissipated northeast of Warren, a distance of about 120 miles, except for a slight curve to the north after leaving El Dorado.

WEATHER FLAGS

The use of weather flags, once a standard practice at all Weather Bureau stations, has been revived recently at Pennsylvania State College. The one phone line to the department of meteorology was often jammed with calls from students, faculty, and townspeople who wanted to know the prospects for weekend trips or day-to-day activities. So a flag code was devised, and now one has merely to glance at the roof of the Mineral Industries building to get the latest indications.

The code uses six flags with four different colors, with sufficient contrast in the colors to insure that no mistakes will be made in reading them. Flags flown in the afternoon predict the weather for the following day; those flown in the morning predict the conditions expected for the balance of the day.

The color code is: white — fair; blue — colder; red — warmer; yellow — cloudy; blue and white checkered — rain or snow; red and blue checkered — strong winds. Any combination of flags may be used to indicate a variety of conditions. The interest of local residents in this new type of "weather bulletin board" has been quite keen.

This Winter's Unusual Weather and Circulation

WILLIAM H. KLEIN, EXTENDED FORECAST SECTION
UNITED STATES WEATHER BUREAU

THE WINTER of 1948-49 was characterized by record cold and snow throughout the western half of the United States along with abnormal warmth in the eastern half of the country, while precipitation was extremely heavy nearly everywhere except in the Northwest and Southeast. This weather pattern first became evident during November, gradually intensified during December, reached its most extreme state during January (see Fig. 1), and began to abate after mid-February.

Closely associated with these weather anomalies were equally well-marked and persistent anomalies of the general circulation. These are best illustrated by the mean sea level and 700-mb charts for January, Fig. 2. Striking features of the sea level chart are:

1. The excess of mass in subpolar regions of the Western Hemisphere and the deficit of mass in the subtropics. As a result the middle-latitude westerlies were abnormally weak (low zonal index), and the western United States was subjected to cold northeasterly winds (like western Europe two winters ago), while the eastern United States enjoyed more maritime conditions than normal.

2. The northward displacement of the Great Basin and eastern Pacific highs, which diminished the frequency of warm dry foehn winds east of the continental divide; and the westward intrusion of the Bermuda high with its attendant maritime tropical air in the eastern United States.

3. The absence of the normal anticyclone track from northwest Canada into the east-central United States. Instead, the polar continental anticyclones either skirted the northern border without penetrating the country or moved due southward into the plateau and warmed up before swinging eastward.

The mean 700-mb chart (which closely approximates the circulation pattern of the entire troposphere) shows a complete reversal of the normal winter pattern in the United States, with a deep trough now located in the West and a strong ridge in the East. As noted in previous studies of the dependence of weather upon the upper air circulation, the area of subnormal surface temperatures has cyclonic curvature and below normal heights aloft, the region of anticyclonic curvature and above normal 700-mb height is situated directly over the area of abnormal surface warmth, and the zone of heavy precipitation is located along and ahead of the trough in cyclonic curvature and southwesterly flow aloft.

Particularly noteworthy is the close parallelism between the direction of the mean con-

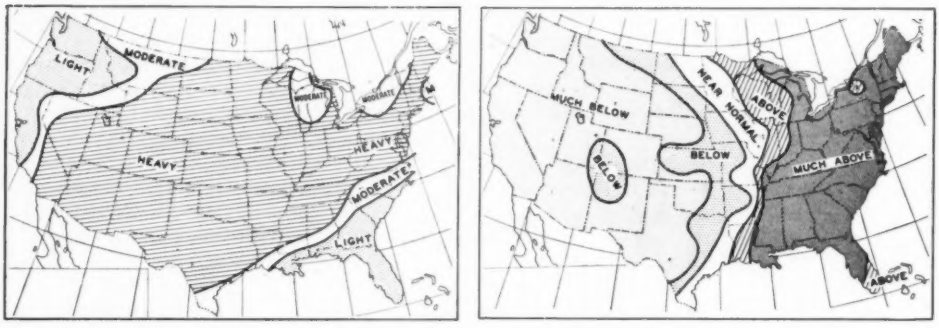


Fig. 1. The diagram on the left shows the observed monthly precipitation anomaly for January, 1949. The classes light, moderate, and heavy occur on the average one third of the time, and therefore have equal probabilities of occurrence. The observed monthly temperature anomaly for January, 1949, is shown at the right. The classes above, below, and near normal occur on the average one fourth of the time, and the classes much above and much below occur one eighth of the time each.

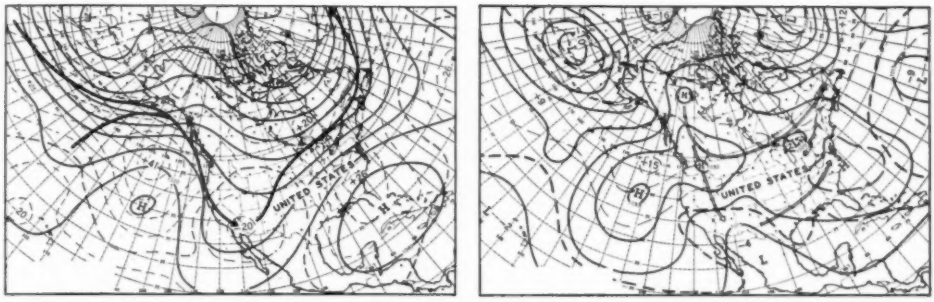


Fig. 2. (Left) Observed mean 700-mb chart for January, 1949. Solid thin lines are 200-foot contours. Dashed lines show departure from normal of 700-mb height, 100-foot intervals, with centers marked in tens of feet. Heavy arrowhead curves are principal cyclone tracks. (Right) January, 1949, mean sea level chart. Solid, thin lines are 5-mb isobars; dashed lines show departure from normal of sea level pressure, 5-mb intervals, with centers marked in millibars. Open arrowhead curves are the principal anticyclone tracks. Diagrams by U. S. Weather Bureau.

tours and the principal storm path. Each cyclone moving down the Pacific Coast into the Southwest (in typical type A fashion*) was accompanied by widespread snow and followed by cold polar outbreaks. As the storms curved northward through the Plains and eastward across the Lakes, they deepened and pulled moist tropical air from the Gulf of Mexico far northward and, in some cases, westward to overrun cold polar air and produce blizzards in the Plains, heavy rains in the Mississippi and Ohio valleys, and mild weather in the East, where the tropical air reached the ground and raised temperatures.

It is important to realize that this winter's circulation features in the United States were only a part of a larger system of regularly spaced waves in the westerlies, with short wave lengths and large amplitudes, extending from the Hawaiian trough eastward to the Azores ridge. A detailed study of the general circulation over the entire Northern Hemisphere during this winter is in progress at the Weather Bureau.

*See "The Weather Types of North America," **Weatherwise**, February, 1949, page 15. — ED.

FLIGHT INFORMATION MANUAL

The *Flight Information Manual*, released February 1, 1949, contains several chapters that will interest readers of *Weatherwise*. One new item is a list of the locations and telephone numbers of Weather Bureau and Civil Aeronautics Association offices where weather information may be obtained, together with a brief mention of the types of weather service available. Elsewhere in the *Manual* are lists of the locations and frequencies of radio stations, both CAA and standard broadcast installations. Schedules and content of CAA weather broadcasts are also discussed.

The *Manual* may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., for one dollar.

METEOROLOGY IN NEW MEXICO

Beginning with the next school year in September, the physics department of the University of New Mexico will offer a combined undergraduate major in physics and meteorology. In addition to general physics and differential and integral calculus, the requirements for the major include a total of 44 semester hours in physics, mathematics, and meteorology, and six additional semester hours of advanced physics and mathematics.

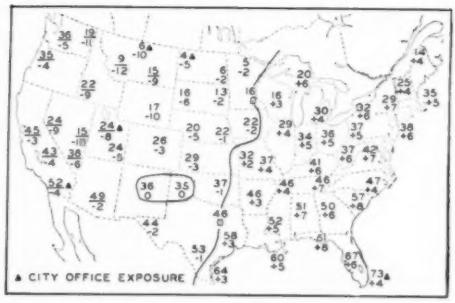
An opportunity to do graduate research in atmospheric physics, leading toward advanced degrees in physics, also is offered to students with a bachelor's degree in physics at New Mexico or elsewhere. For further information, communicate directly with the Department of Physics, University of New Mexico, Albuquerque, N. M.

THE 1948-49 WINTER

D. C. CAMERON

NOT IN NEARLY 60 years has there been a winter like the one just concluded. The persistence of cold in the western half of the country (see chart), plus record-breaking snow, and the unusual warmth in the eastern half were its outstanding features. The previous time that a whole winter maintained the cold-West warm-East balance was in 1889-90. There have been instances of colder individual winter months, but the season as a whole seems to have set the record. At Helena, Montana, where the 1948-49 mean was 9° (12° below normal), the previous coldest winter was 1889-90, but the three-months mean then was only 15.5°. Throughout the East, the winter of 1931-32 was by far the warmest, but during that season the West was not persistently cold. No stations in the East had the warmest winter during the season just closed, those of 1879-80, 1881-82, 1889-90, and 1931-32 having been warmer at many points.

In this latest western winter, no all-time record low temperatures occurred over any wide area; instead there was a persistence of moderate to severe cold from mid-December to mid-February. As for snow, never in the history of transcontinental train travel had service on a main line been interrupted as long as it was on the Union Pacific through Wyoming, and for lesser intervals in Utah, Nevada, and Idaho. While the run-off will be beneficial in most areas, the water content of the snow in much of California and Nevada was below normal, because of the prevailing low temperatures. At Salt Lake City the winter was the snowiest on record, but the water content of 4.48″ (December-February) has been exceeded 28 times in 75 years, due largely, however, to the occurrence of liquid precipitation, not uncommon in normal winters there.



The mean temperatures and departures for the winter of 1948 (Dec.-Jan.-Feb.). Underscoring indicates the coldest winter of record. The irregular line marks the division between below normal and above normal average temperatures.

Perhaps the most fortunate place in the West was Albuquerque, where both temperature and snowfall turned out to be almost exactly normal, every other area within or west of the Rockies breaking some snowfall or temperature record. Weather Bureau statements are illustrative:

Spokane: " . . . for 99 straight days (mid-November into February) the minimum temperature went below freezing, and on 23 of those days the minimum was zero or lower. On 58 of the 99 days the maximum remained below freezing. The 29 inches of snow on the ground at one time during February was the greatest depth ever measured here."

Ely: " . . . total snowfall of 48″ through February . . . much in excess of any previous winter. Both December and February were near record for lowest means; the January mean was 13° lower than any previous January and the absolute minimum of −27° was 7° lower than the previous record."

Cheyenne: " . . . only new record established was the wet January, 2.78″, heaviest on record, but during February only 0.01″ fell, making it the second driest February of record."

LETTER TO THE EDITOR

(Continued from page 26)

not getting better, as nighttime temperatures dropped way below freezing (nine nights below zero).

Three months totaled 153.9 inches of snow, or 12¾ feet! This was 11.92 inches of precipitation, or nearly double the normal 6.28 inches. In the 74-day period, records were established that are not likely to be broken for several years. Everyone throughout this snow-stricken area is unanimous in saying that this has been the toughest, roughest, and most severe winter on record.

PAUL W. SORENSON
Official-in-Charge,
Flagstaff Office, USWB

Amateur Weathermen of America

For information on membership in the Amateur Weathermen of America, write to David M. Ludlum, Director, AWA, Franklin Institute, Philadelphia 3, Pa.

AWA ASSISTS RADAR PROJECT

NEW YORK will have radar eyes this summer to keep tabs on all unexpected visitors in the form of thunderstorms and heavy rain showers. Too often in the past thunderstorms have formed over the tri-state area where New York, New Jersey, and Pennsylvania come together and where there are no regular reporting weather observation posts. Many times the first sign of an approaching storm was a blackening of the western sky, and even that gave little clue as to the exact course of the storm. Last year, much to the embarrassment of the forecasters, a quick-breaking thunderstorm rained out a baseball game at the Yankee Stadium with over an inch of rain, while the Dodgers, only six miles to the south in Flatbush, played under sunny skies.

A scientific approach will be made this summer to this problem of thunderstorm tracking, and members of the AWA have been invited to assist in gathering the basic data. An AN-APQ-13 radar set has been lent by the Air Forces to the New York Weather Bureau, where it will be installed atop the lofty Whitehall Building which commands a clear sweep to the south and west over New York Harbor. The radar will be manned 24 hours a day, and it is anticipated that all thunderstorms, rain showers, cold and warm fronts will be detected as they approach the city. The radar will operate in the 10,000-megacycle group with a three-centimeter wave length. Although this apparatus has a normal range of 100 miles, it is hoped that some echoes can be found as far as 300 miles from New York.

This will mark the first installation of radar for meteorological purposes in a large city of commerce. At the present time, the Weather Bureau maintains experimental radars at Norfolk, Nebraska; Wichita Falls, Texas; Wichita, Kansas; and Washington National Airport, Virginia. It is expected that the many users of the city office service will benefit from more accurate thunderstorm forecasts.

Members of the AWA in the New York area and within 100 miles of the city have been requested to assist. It is especially important that the times of beginning and ending of precipitation, and the amounts, be noted in all areas covered by the radar scope. These will be forwarded to the New York Weather Bureau on postcards, and the data plotted on maps so that the radar scope pictures can be correlated with the actual rainfall. Thus, the local peculiarity of thunderstorms may be determined in a scientific manner.

All AWA members who would like to assist are requested to write the New York Weather Bureau, Attn: Mr. James McGuire, Whitehall Bldg., New York 4, N. Y.

THE NATURE OF TORNADOES

(Continued from page 30)

town section of a city, the escaping of death or serious injury is largely a matter of luck. The safest place is probably a lower floor of a building, preferably a modern steel-reinforced structure, flattening one's self against the wall of a hallway, which might support falling timbers and other debris. In any event, stay away from windows; flying debris is likely to come through them with killing force.

Tornadoes usually break out early in the calendar year in the states along the Gulf Coast, and the belt of their occurrence gradually extends northward as spring progresses. May and June are the months of greatest frequency in the middle latitudes of the country. Tornadoes have been reported at all hours of the day and night, but are more frequent in the late afternoon. In Kansas, where records of these storms have been carefully tabulated since 1913, nearly 17 per cent have occurred between 5 p.m. and 6 p.m., the hour of greatest frequency, and 75 per cent have occurred between noon and eight o'clock in the evening.

FORECASTING THE WEATHER

The Weather Types of North America—2

ROBERT D. ELLIOTT

AMERICAN INSTITUTE OF AEROLOGICAL RESEARCH

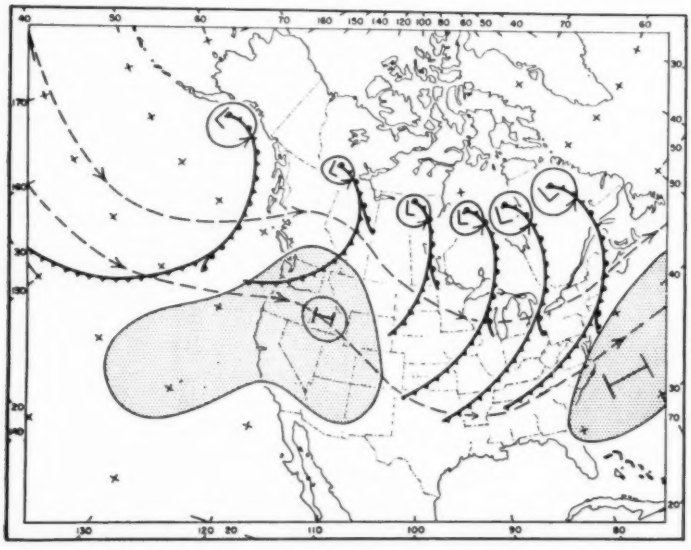
IN THIS DEPARTMENT in February, there appeared a discussion on the basis for weather types, along with schematic diagrams and descriptions of North American weather types **A** and **B.** In this issue, four additional types will be described.

In the original North American weather types, there were two in which the dominant feature was a persistent high pressure area in the Great Basin. This high served to deflect Pacific storms entering North America to the north of their normal path, thus maintaining generally fair weather in the western United States. In one of these types, **Bn (B north),** the high was located in the northern Great Basin, whereas in the other types, **Bs (B south),** the high was smaller and farther south. In both types, the mean upper-air flow pattern had a crest in the West and a trough in the East. Subsequent refinements of the original typing scheme showed that type **Bn** really consists of three distinct but closely related types. The mean upper-level flow pattern is sufficiently different in each type so that polar outbreaks of different character are associated with them. Thus, type **Bn-a** is characterized by only a very minor outbreak that affects principally eastern Canada and the northeastern United States. The **Bn-b** has associated with it a rather intense polar outbreak that moves southward into the Great Plains. The trough aloft is deeper than in **Bn-a. Bn-c** has an outbreak that moves down both east of the Rockies and over the Rockies. The mean upper-level crest is farther west in the third type than in the others. Type **Bs** remains the same as in the original typing.

As in the preceding issue, the types are here represented by schematic diagrams, each diagram covering the number of days required for one cyclone to advance eastward across North America. The mean upper-level flow for each type is indicated by dashed lines and arrows. Areas of persistent high pressure are delineated by stippling and double arrows indicate the trajectories of major polar outbreaks. Successive daily positions of a single cyclone and its associated frontal system are shown in conventional weather map fashion.

The descriptive material pertains to the winter season. Type characteristics vary only slightly with season, and the well-known seasonal climatic differences are primarily the result of seasonal variations in the frequencies of occurrence of the types.

TYPE Bn-a OF NORTH AMERICAN WEATHER TYPES



TYPE Bn-a

Type **Bn-a** (called **B north a**) is a meridional flow type with an upper-level crest in the West and a trough in the East. The mean crest position is at 115° to 120° west, and the mean trough position is at about 90° west.

At the surface, the presence of a strong high pressure area in the Great Basin is the outstanding feature, and is responsible for clear weather with warm days and cool nights in the Rocky Mountain and Pacific Coast states. In the Gulf of Alaska there is present a semi-permanent low from which an occluded front moves eastward over the Rockies and into the prairie provinces. As is shown in the diagram, the low center moves eastward through northern Canada, the front sweeping quite far south into the United States. However, the air masses associated with this front are relatively dry and the temperature contrast across the front is small.

Because of the northerly path of the low, precipitation of consequence is largely confined to northern and central Canada while the United States in general experiences dry weather. Greatest amounts in excess of normal occur along the southeast Alaskan and British Columbian coasts.

Only a small outbreak of cold polar air occurs and this affects principally eastern Canada and northeastern United States. For this reason, temperatures may be near normal or slightly below in eastern Canada and the northeastern states, but elsewhere they are generally above normal.

The above remarks pertain to the winter season; however, this type occurs more frequently in summer than in any other season. During the summer, precipitation is more general throughout the east and above normal amounts of rain can be expected in northeastern sections of the United States.

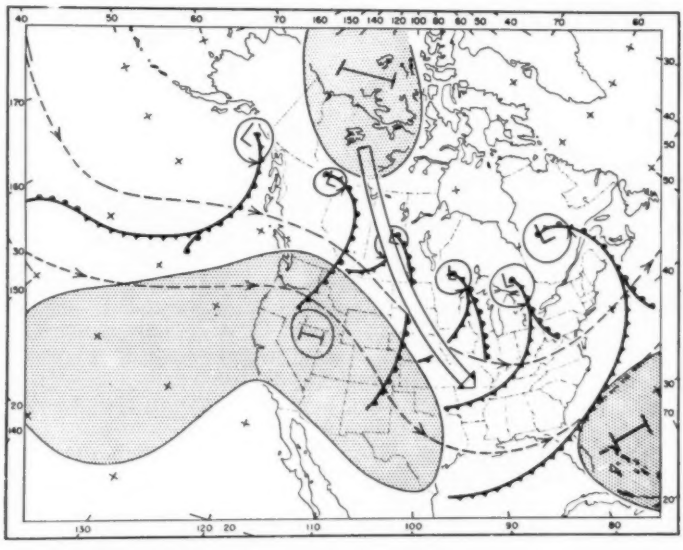
TYPE Bn-b

Type **Bn-b** (called **B north b**) is a meridional flow type characterized by an upper-level crest in the West and a trough in the East. The mean crest position is at 115° to 120° west and the mean trough is near 90° west.

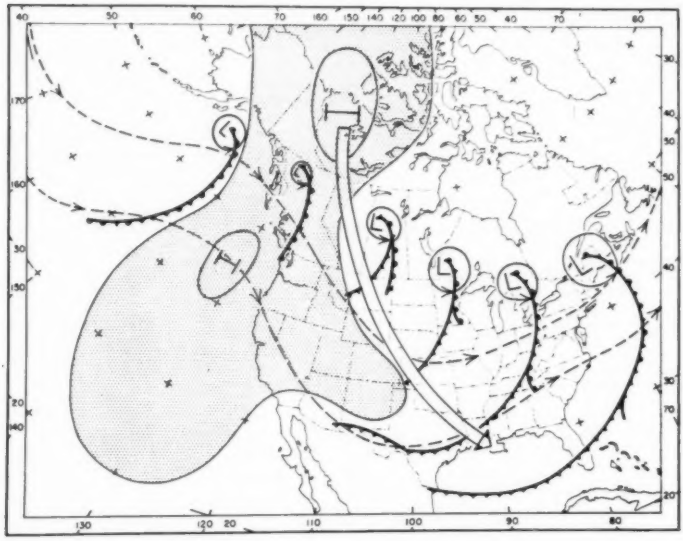
At the surface, the strong and persistent Great Basin anticyclone is effective in maintaining clear weather in that region by diverting Pacific storms northward as they enter the North American continent. The low moves eastward through northern Canada, and a cold front develops behind it in the prairie provinces, bringing a great mass of cold air south-southeastward just east of the Rockies. This outbreak distinguishes **Bn-b** from **Bn-a,** which it resembles in other respects. The cold air penetrates far to the south and on occasion may move through the Gulf of Mexico and thence across the narrow portion of Mexico and into the Pacific Ocean, being evidenced in this region primarily by strong winds. This type is normally responsible for the first frosts of the season in the produce areas of southern Texas. As the cold high moves east, frosts may also occur in Florida.

Because of the influx of cold air into the United States east of the Rockies, the low moves

TYPE Bn-b OF NORTH AMERICAN WEATHER TYPES



TYPE Bn-c OF NORTH AMERICAN WEATHER TYPES



farther south than in type **Bn-a** and the trough aloft is deeper. For this reason, considerable cloudiness and precipitation occur in the Great Lakes and New England regions. Often, with this type, waves develop in the eastern Gulf of Mexico or off the East Coast that may produce good precipitation in seaboard areas.

Precipitation is below normal on the West Coast and in the Rocky Mountain region as far north as the 50th parallel. East of the Rockies, precipitation is above normal in the Great Lakes and New England states, but elsewhere is near or below normal excepting for spots of above normal in the Gulf or East Coast states in connection with the above-mentioned wave developments.

Temperatures are generally above normal from the Rocky Mountains westward and generally below normal to the east. A few spots in the Great Basin area experience so much radiational cooling that low minimum temperatures overbalance high maximum temperatures and the average is below normal.

This type occurs most frequently in the autumn, next in the spring. The first occurrence in autumn and the last in spring often represent the first and the last cold waves of the winter season. These cold waves are normally accompanied by considerable wind in the Great Plains region and in the Middle West.

TYPE Bn-c

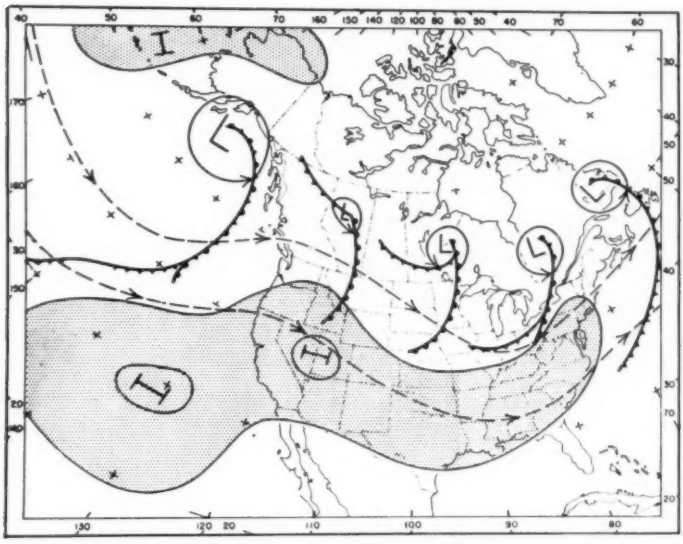
The meridional flow type **Bn-c** (called **B north c**) has the characteristic **Bn** upper-level flow pattern with a mean crest located in the West and a trough in the East. The crest is unusually far to the west (about 135° west) and the trough is similarly abnormally far west (about 100° west).

In this type, the eastern lobe of the Pacific high is north and east of its normal position, thus sheltering the West Coast of the United States from storms. However, an outbreak of cold air from northwestern continental regions moves south then southeast, following a trajectory to the west of the normal path of cold outbreaks. This is responsible for forcing the low entering British Columbia to move more to the south than it might otherwise do. Indeed, in many cases, the low moves as much as 10 degrees of latitude south of the path indicated in the diagram, or a secondary crescent-shaped low of major importance develops in Colorado. Since behind the cold front east winds blow the cold air upslope to the forward wall of the Rockies and over into the Great Basin, blizzard conditions are experienced in these regions. Usually, in later stages, a closed low pressure center forms aloft over the southern Great Basin area and is responsible for the maintenance of foul weather there. When a series of **Bn-c** types occurs, or when a number of **Bn-c** types are each followed by a **C** type (to be discussed later), then very rigorous winter conditions prevail in the West, as evidenced by the winter of 1948-49.

Under normal circumstances, type **Bn-c** will produce greatest above-normal amounts of precipitation in the Mississippi and Ohio valleys, as with type **A.** Precipitation is also somewhat above normal in the Rocky Mountain and western Great Plains regions. Elsewhere, precipitation is below normal.

Temperatures are below normal in the West

TYPE Bs OF NORTH AMERICAN WEATHER TYPES



and above in the East, where exceptionally mild weather is the rule.

Although this type occurs at all times of the year, it is most frequently observed in August and September, and while milder in character during these months than in midwinter, it is nevertheless responsible for the light snowfalls which occasionally occur as early as late August or September in the Rockies and in some of the Plains area next to the mountains.

TYPE Bs

Type **Bs** (called **B south**) is quite similar to **Bn-a** in that the mean positions of the principal upper level trough and crest are in the same situations. However, in **Bs** the eastern trough is deeper and the western crest less intense than in type **Bn-a.**

In the mid-Pacific there is a high pressure ridge of cold air which "dangles" south from the Aleutians. This causes waves to develop just north and east of Hawaii. These waves deepen as they move northeastward to the extremely deep semipermanent low pressure center in the Gulf of Alaska. A small portion of this low breaks off as a frontal system moves eastward across the Rockies. A relatively small but intense Great Basin high prevents storminess in California but southwest gales and moderate to heavy precipitation are to be expected in the Pacific Northwest and British Columbia. As the low moves east of the Rockies, chinook winds prevail from Cheyenne to Calgary, often with gale force. As the low progresses eastward, it intensifies and moves just to the north of the Great Lakes, causing considerable precipitation in that region. The movement of the low from the Rockies eastward is extremely rapid and may be followed within two days by another similar low.

In southern California, due to the presence of high pressure in the Great Basin, conditions are favorable for the development of "Santa Ana" winds. These strong, dry, gusty winds do considerable damage in coastal regions. Although these winds occur most frequently in connection with type **Bs**, they may occur also in the **Bn** types.

Precipitation is in excess of normal in the western part of the Pacific Northwest and in British Columbia. It is near normal or above in eastern Canada; elsewhere, it is generally below normal.

Temperatures are generally above normal except in eastern Canada and the northeastern states where they are below or near normal.

This type occurs most frequently in late autumn or early winter.

Weather Exchange

Classified advertisements for this column are 8 cents a word, including address; minimum ad 20 words. Remittance must accompany orders. Write Weatherwise, AWA, The Franklin Institute, Phila. 3, Pa.

AMATEURS, professionals, technicians, inquire about selling, trading, your slides, stripfilms, photos. Many subjects. Slide Foundations, Dept. 4, Box 413, Alameda, Calif.

FOR SALE: Secondhand direct reading anemometer. Good condition. Write Gerald Phillips, Clough Road, Waterbury, Conn., for details and price.

WORKSHOP FOR WEATHERMEN

CONDUCTED BY CHARLES A. LAIRD

How to Construct An Anemometer

MOST COMMON INSTRUMENT for determining wind speed is the cup anemometer. Simply described, three or four hollow cups or cones are mounted on horizontal arms, supported by a vertical shaft. Air moving past the cups rotates the assembly, and the speed of rotation bears a relation to air speed.

The cup anemometer was invented by Robinson, who assumed, falsely, that regardless of size of the cups and length of the cup arms, the speed of rotation in relation to wind movement was constant for all anemometers. Not only has this since been proven wrong, but it has also been discovered that the relation of wind movement to anemometer rotation is not constant at all wind speeds. Mathematical formulae have been used to calibrate anemometers, and instrument makers resort to wind tunnels for establishing the accuracy of their products. Such elaborate methods are, of course, beyond the scope of most amateur weathermen, but a simpler method of calibration can be used for the anemometer described here.

In the simplest anemometers, speed of the vertical shaft is reduced by gears, and an electrical contact is made each time the shaft revolves a definite number of times — for example, 25. A simple electrical circuit, consisting of buzzer, battery, and switch, is wired in series with the anemometer contacts. This is the same as a common doorbell circuit. When the switch is turned on, the buzzer sounds each time the anemometer cups rotate 25 times. If the dimensions of the cup assembly are such that the assembly rotates 1,500 times for each mile of wind, each buzz indicates that 1/60 mile of wind has passed. In other words, the number of buzzes in a one-minute period equals the wind speed in miles per hour. A great many of the anemometers used at weather stations operate in just this manner. The indicated speed is not always correct at all speeds, and corrections are usually applied at very low and very high wind speeds.

The three cones used in the anemometer described here are made of thin copper and have a diameter of 2" at the open end. The angle of the cone should be about 90 degrees. Each of the cones is soldered on one end of a 4½" section of ⅛" round shafting, as shown above. The vertical shaft should have a diameter of at least ⅛", but this dimension may vary, depending on the gears obtainable. The three cone arms are soldered into holes drilled an equal distance apart in a section of round brass stock about ½" long. The vertical shaft is soldered in a hole drilled to accommodate it in the section of brass stock, so that the shaft is perpendicular to the cup arms. A cone-shaped rain shield may be added to the cone arm assembly (Fig. 1).

Two sections of iron pipe ⅜" inside diameter serve as a support for the anemometer. The upper section should be 6" long and the lower, 2" to 4". Two floor flanges serve to separate these pipe sections, held together with pieces of ⅛" by ⅜" brass stock, bent and drilled as shown in Fig. 2. The floor flanges, forming the top and bottom of the gear housing, should be about 3" apart, but this may be varied, depending on the sizes of the gears used. The top bearing for the vertical shaft is a brass plug, forced in the top of the pipe support and drilled to accommodate the shaft. The bottom bearing is similar, but drilled only part way through. The vertical shaft is rounded off at the bottom end and rests in the plug, as shown in Fig. 2.

Worm-and-pinion gears are used for speed reduction. They should have a ratio of about 1 to 25, although this, too, may be varied. The worm is mounted on the vertical shaft and the pinion gear is supported by a short horizontal shaft, turning in bearings made of two sections of ⅜" by ⅛" brass stock, which are bolted to the floor flange forming the bottom of the gear housing. Two collars are mounted on the ends of the shaft carrying the pinion gear.

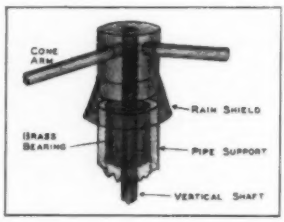


Fig. 1. Details of the upper bearing showing how to assemble properly the vertical shaft, cone arms, and rain shield.

The gears may be of the type used in toy construction sets, such as Constructioneer or Erector. Or you may get them out of an old electric clock. A thin brass strip mounted on a block of insulating material, such as fiber, makes contact with the setscrew in one of the collars, so that a circuit is closed once for each revolution of the pinion gear. The fiber block is bolted to one of the upright sections of brass stock forming the pinion bearing. The brass strip must be insulated from the rest of the anemometer. A sheet metal cover slips over the gear housing, protecting the gears from rain.

To hook up the anemometer, run a wire from the brass strip to one terminal of a battery consisting of two dry cells. A wire from the opposite terminal of the battery goes to a switch, then to one side of an ordinary buzzer. Run another wire from the other terminal of the buzzer to the body or ground side of the anemometer. Now, when contact is made in the anemometer, the buzzer will sound. The wires running to the anemometer may be of any reasonable length, although you may have to add another dry cell or two if they are very long. Use No. 16 wire or larger.

To calibrate the anemometer, mount it on a stick or section of pipe so it can be held outside of an automobile window and somewhat higher than the top of the car. Have someone drive

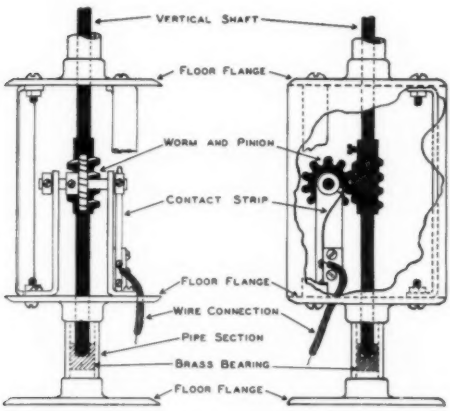


Fig. 2. Front and side view of gear box.

the car at a constant speed, and find the time in minutes and seconds that it takes the anemometer to contact the buzzer the number of times represented by that speed. Thus, if the speed is 10 miles per hour, the time required is that for 10 buzzes; if it is 15 miles per hour, the time for 15 buzzes is measured; 25 buzzes for 25 miles per hour, and so forth. Now turn the car around and repeat this procedure in the opposite direction. Use the average time obtained from driving in both directions. This is to compensate for (average out) the natural wind velocity at the time. If you can do this calibrating on a calm day, the results will be more accurate, and they can be further improved by increasing the number of test runs in opposite directions. Use the average figure for all the calibration runs.

But the anemometer may not respond to very high and very low winds in quite the same way. Thus at 40 miles per hour the number of buzzes in the unit time may be more or less than 40, indicating that a correction to high-speed readings is necessary. In fact, the best way to record the calibration is to try as many car speeds as possible and draw up a curve of the averages.

Note here that we have made no attempt to construct our anemometer so that it operates in accordance with the example given at the beginning of this article. In other words, while a one-minute unit of time is convenient, it is not essential. Thus, in our calibration system described above, we know the automobile's speed and arbitrarily choose to have each buzz represent one mile of wind speed. Therefore, the time required to produce the number of buzzes equal to the automobile's speed becomes the basic unit of time for our anemometer.

After it is calibrated, the anemometer may be mounted for use. Place it as high as possible on a housetop or a long pole, and do not situate it near obstructions or passages where the wind cannot blow freely. But the instrument must be easily accessible so you can keep the bearings lubricated with light oil. Wire it up, turn it on, and count the buzzes in the period of time determined in the calibration runs. This will equal the wind speed in miles per hour.

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RAINFALL AND RUNOFF

Edgar E. Foster. The Macmillan Company, New York, 1948. 468 pages, 179 figures. $9.00.

THE AUTHOR of this book states in the preface that first it was desired to present a reasonably complete picture of the science of hydrology as related to rainfall and runoff, including recent developments. His second aim was to show the application of statistical methods to many hydrological processes. The book's greatest interest results from the efforts of the author directed toward this latter objective.

Although statistical treatment of hydrologic data is stressed it is not, in general, discussed as a distinct subject but is introduced unobtrusively into the phase of hydrology under consideration. For example, in discussing humidity it is shown that there is small correlation between the vapor pressure on successive days in January at Boston. Later, in the discussion of thunderstorms it is demonstrated that the monthly frequency of thunderstorms at Eastport, Maine, fits well the distribution computed from Poisson's law of small numbers. In the chapter on the distribution of precipitation, the advantages and disadvantages of using the median rather than the mean as precipitation normals are discussed.

Particularly interesting is the example showing in detail the method of computing the frequency of various 24-hour precipitation amounts at Concord, New Hampshire, using Slade's partly bounded asymmetrical function. This function gives a definite probability to any amount, no matter how large, an aspect discussed in some detail in the chapter on floods and flood frequencies. However, the author's presentation is by no means conclusive enough to settle the controversial problem of how great an extent we can depend upon the past records to indicate future probabilities. After advocating strongly the use of statistical methods in hydrology the author, in discussing what he calls "the probable maximum flood" in the closing pages of the book, recommends the use of storm transposition with moisture adjustment.

In spite of the deliberate bias, the book is by no means all statistical. The chapter on air masses, aside from contributing nothing new in context or viewpoint, has little direct connection with the remainder of the book. The succeeding chapter, "Storms Which Produce Precipitation," is not as well done as are those dealing with subjects with which the author is more familiar. There is a chapter each on snow, evaporation, ground water and runoff, although runoff and the associated phenomenon, infiltration, are treated more briefly than the title of the book would tend to indicate. The unit hydrograph is discussed briefly and the distribution graph treated rather fully. There is no mention of any method of preparing stream flow forecasts for rivers draining areas so large as to prevent the application of the unit hydrograph.

Numerous examples of careless editing, possibly confusing to the student, were noted. For example, on pages 25 and 59 two different formulas for specific humidity are given. A formula relating total precipitation and precipitation rates is given incorrectly on page 43, but on page 129 is stated correctly using differing symbols. Although heavy rains in connection with both tropical cyclones and orographic barriers are discussed, the author later makes the unqualified statement, "Heavy precipitation can be caused only by the lifting of a warm moist tropical air mass over one of colder air."

The author has definitely succeeded in demonstrating a great opportunity for statistical treatment of hydrologic data. Meteorologists reading the book will undoubtedly see similar opportunities in their own fields. Because of some omissions, the book is only partly successful in presenting a reasonably complete picture of hydrology. A bibliography consisting of 200 entries, mostly recent, will guide the reader to more complete material on the subjects discussed.

DALE R. HARRIS
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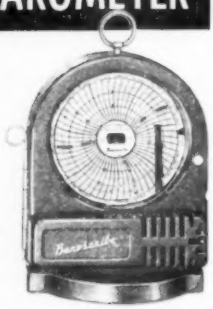

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